Radiometric Calibration of IKONOS using Ground-Reference Test Sites

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Introduction

Talk Overview

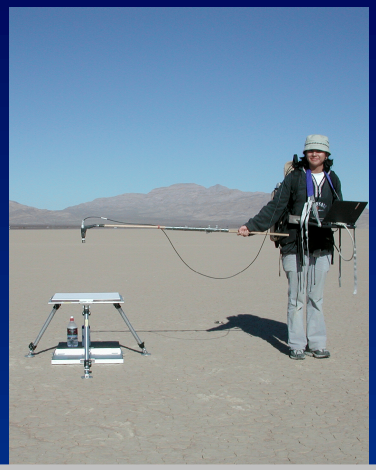
- Describe the reflectance-based results for the multi-spectral bands of IKONOS
  - Test site discussion
  - Data collected for 8 different dates and five different sites
  - Description of the measurements
- Results from work with other sensors for comparison
- Uncertainty estimates
- Conclusions

Introduction

Data sets used

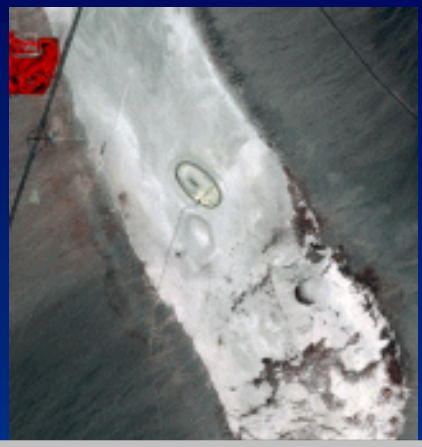
- Six data sets from 2001 using University of Arizona test sites
  - July 13 - Lunar Lake Playa
  - July 13 - Railroad Valley Playa
  - July 16 - Lunar Lake Playa
  - July 16 - Railroad Valley Playa
  - September 2 - White Sands Missile Range
  - November 19 - Ivanpah Playa
- Four data sets from South Dakota State University test site in Brookings
  - July 3
  - July 17
  - July 25
  - August 13

Reflectance-based approach



Measured Surface Reflectance

Measured Atmospheric Parameters



Average Test Site DN from IKONOS Imagery

Radiative Transfer Code

IKONOS At-sensor Radiance

Predicted At-sensor Radiance in IKONOS Spectral Bands

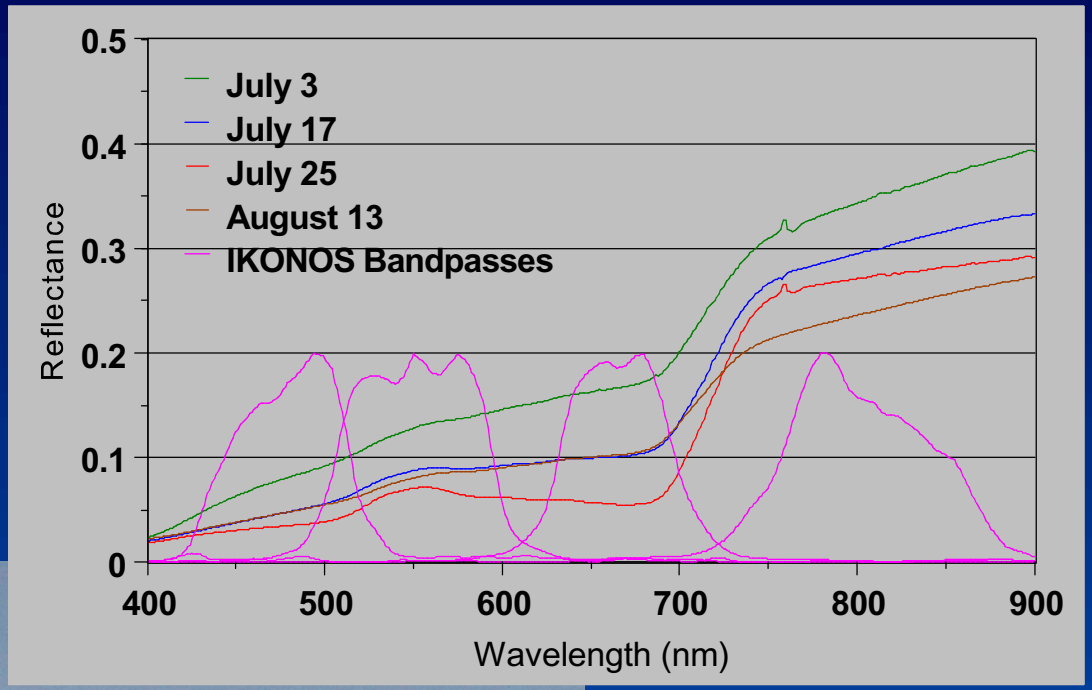
Evaluation of IKONOS Calibration

Test sites

Results shown here rely on two test site types

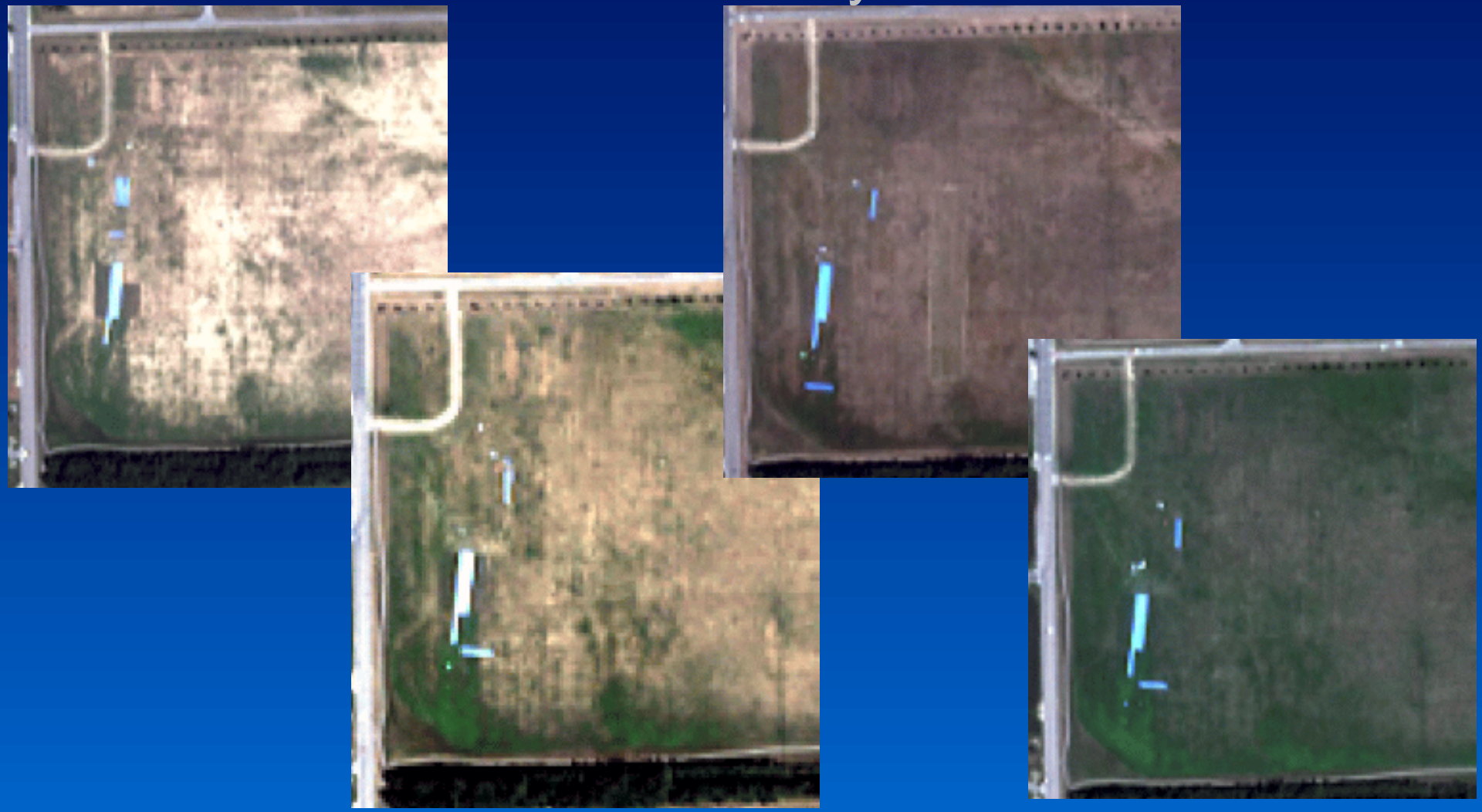
- Type 1 is the large homogeneous unvegetated sites
  - Flat spectral response in IKONOS bands 2, 3, and 4
  - High reflectance
  - Ivanpah Playa, Railroad Valley Playa, Lunar Lake Playa, White Sands Missile Range
- Type 2 is a vegetated site
  - Brookings, South Dakota
  - More realistic surface
- Both are useful and necessary
  - Surface reflectance can be characterized at both sites at time of sensor overpass
    - Sizes of areas characterized are relatively small
    - Sites can be walked on with minimal impact
  - Different radiative transfer situations

Brookings Test Site

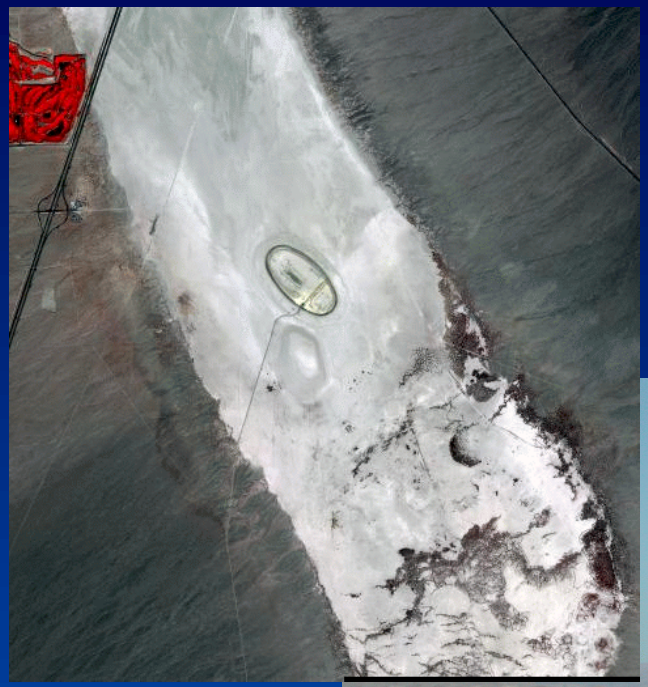


Brookings site

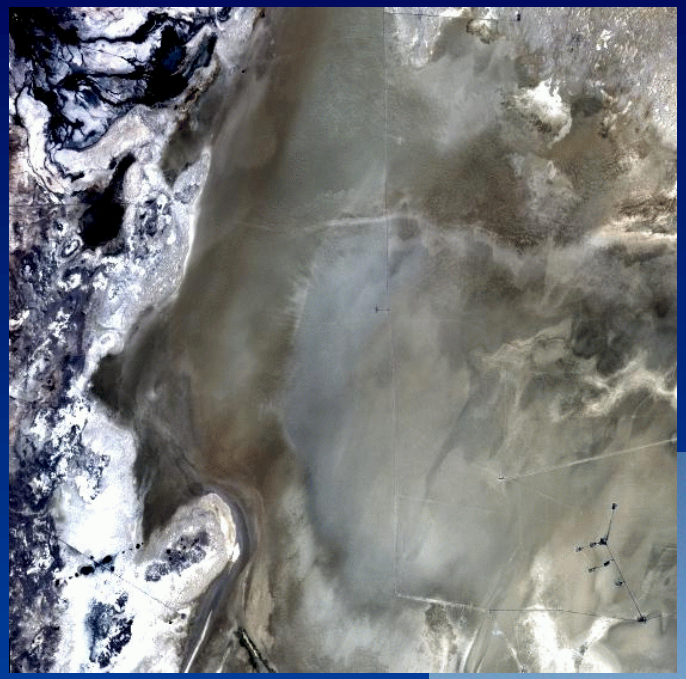
Spatial and temporal variability must be characterized accurately



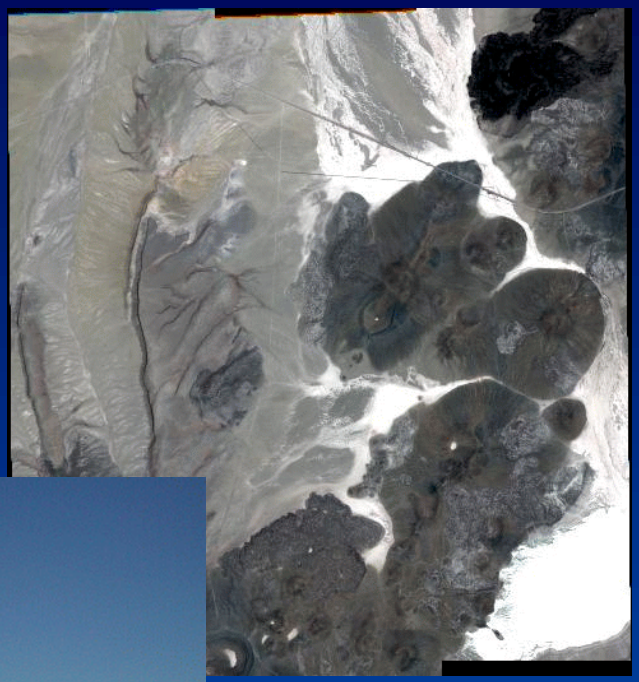
Ivanpah Test Site

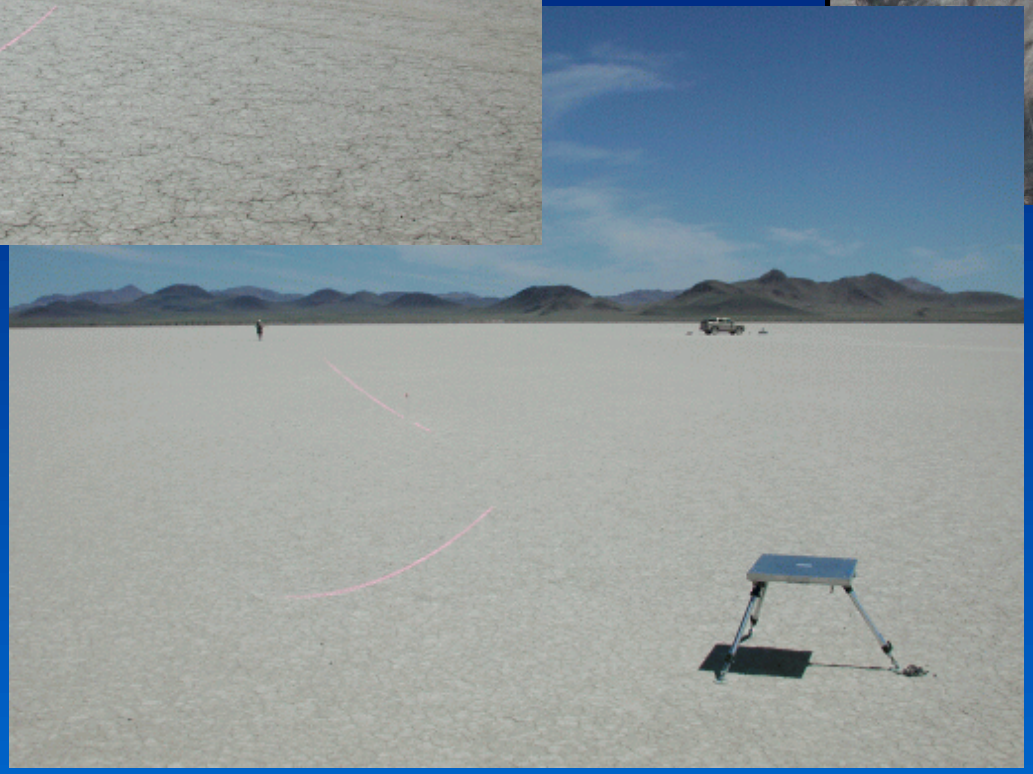


Railroad Valley test site

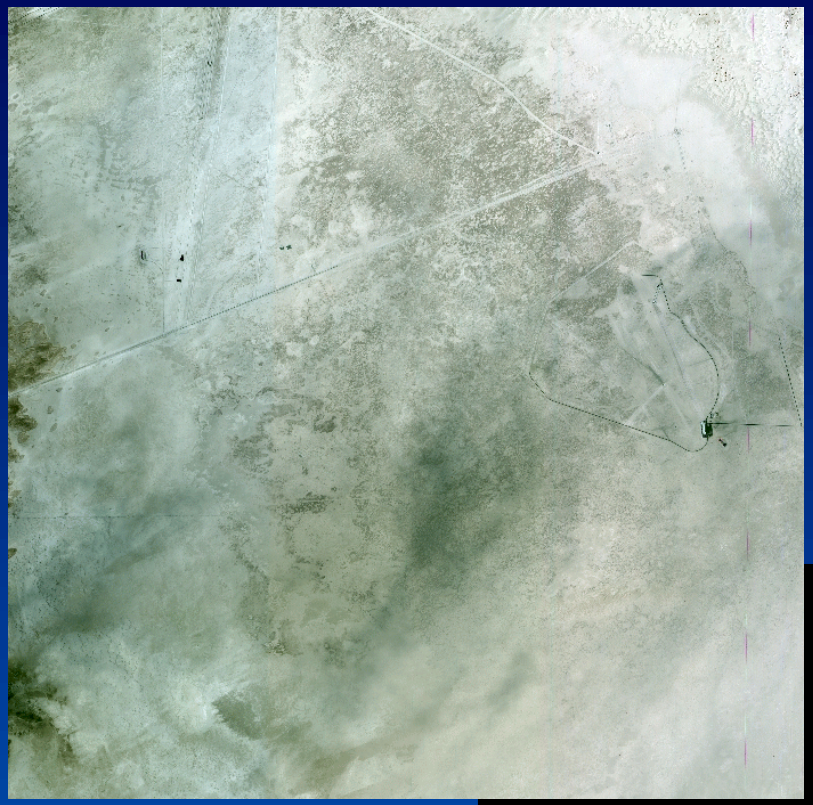


Lunar Lake test site





White Sands test site



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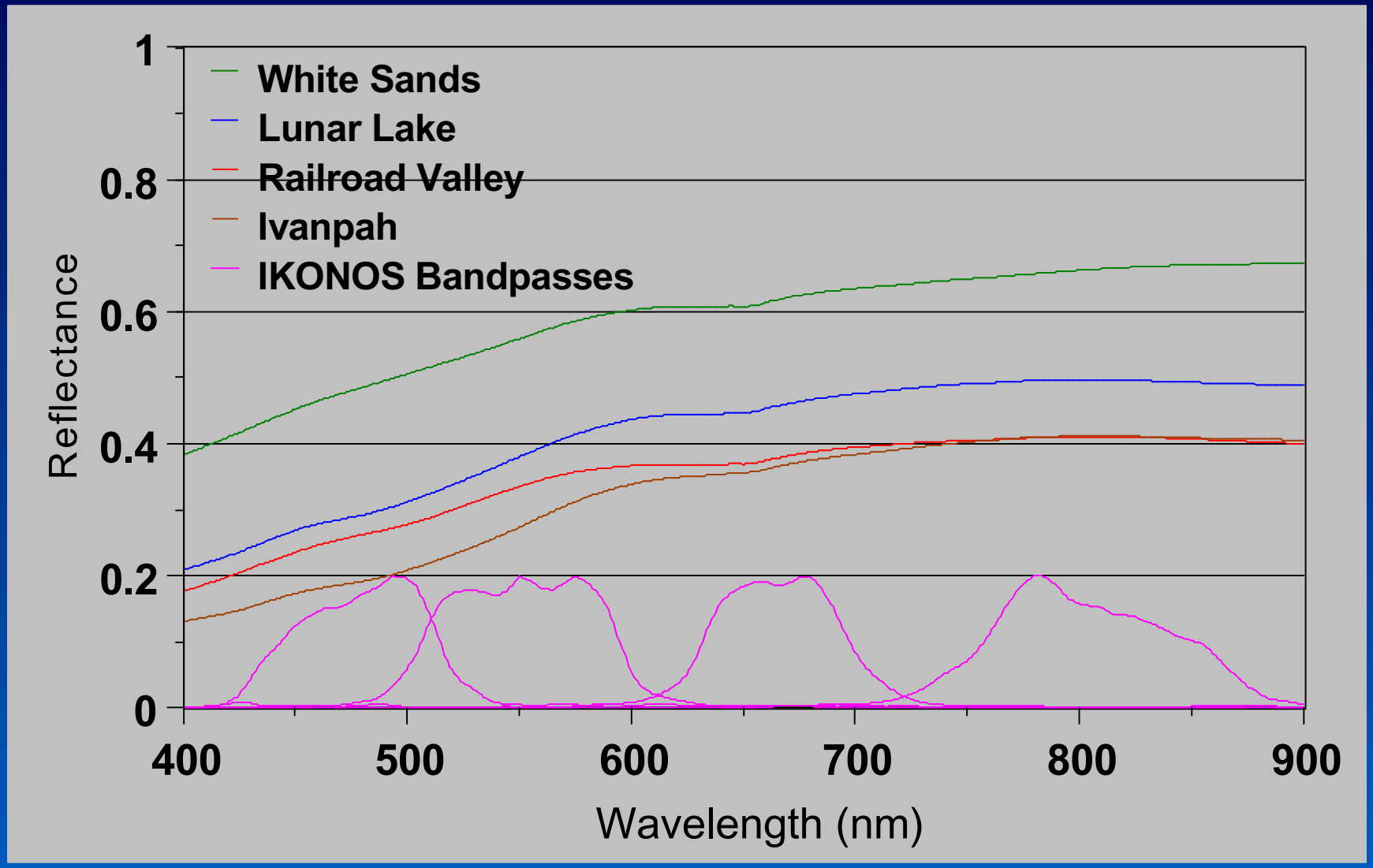
Playa surface reflectance

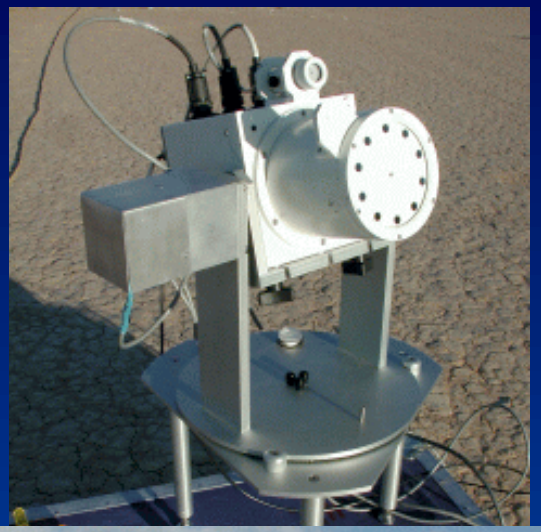


Surface reflectance measurements

Surface reflectance determined by referencing measurements of the upwelling radiance from the test site to those of a panel of known reflectance

Atmospheric measurements

Required atmospheric inputs aerosol type and amount, column ozone, column water vapor

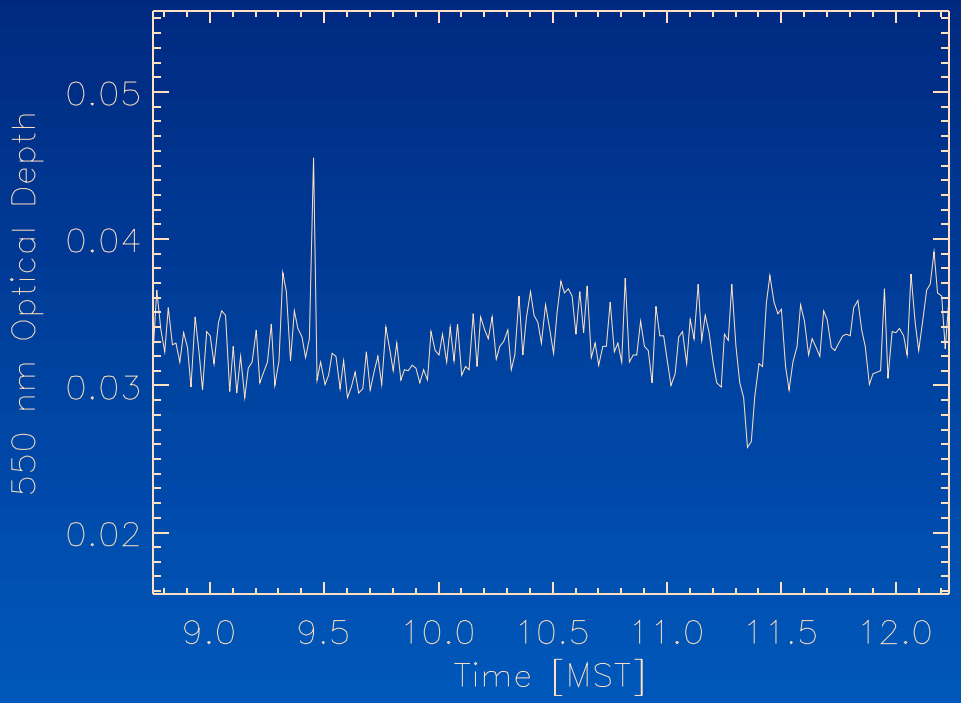


- Atmospheric measurements rely on a 10-band solar radiometer to retrieve spectral transmittance
  - Developed in the Electrical and Computer Engineering Department under supervision of John Reagan
  - Automated system with 10 separate detector/filter combinations in the visible and near-IR

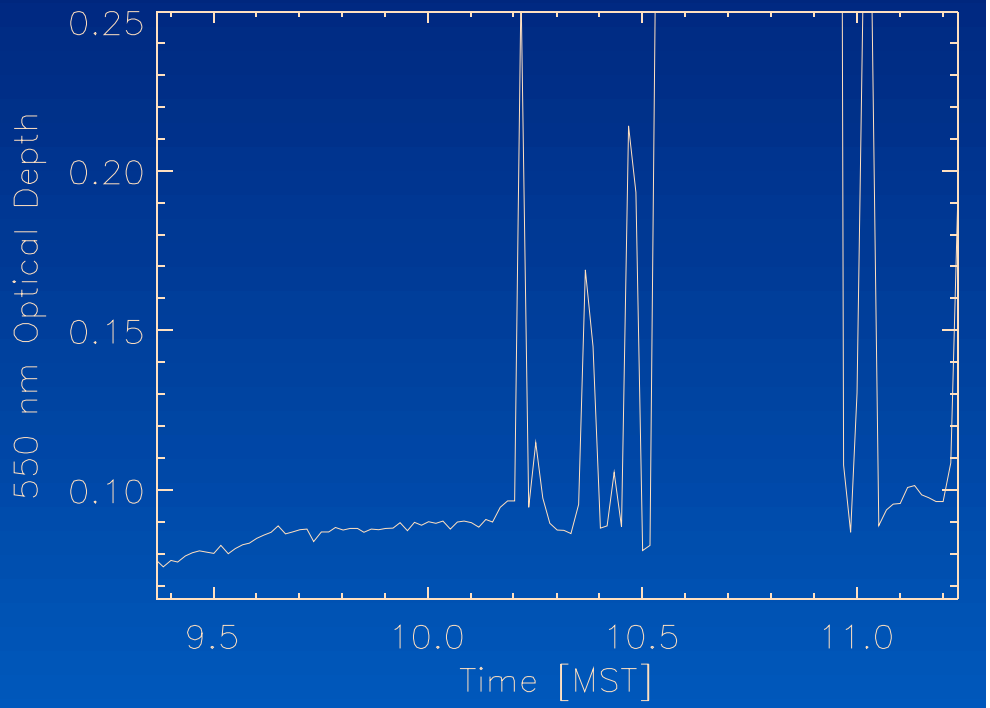
Example atmospheric results

Results below show optical depth from a clear day at Lunar Lake versus a cloudy day at White Sands

Lunar Lake



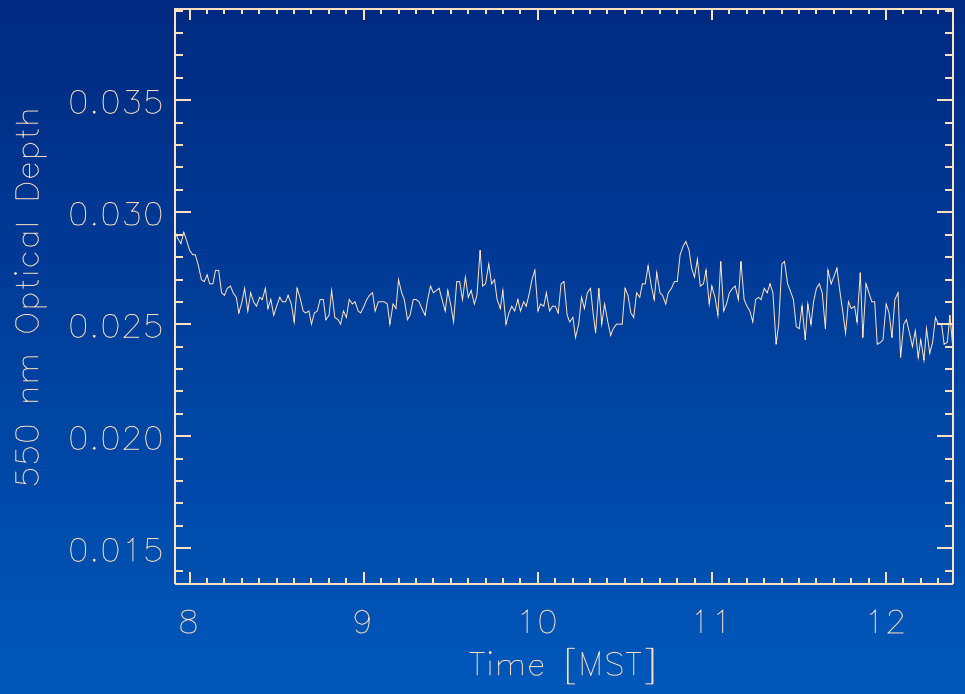
White Sands



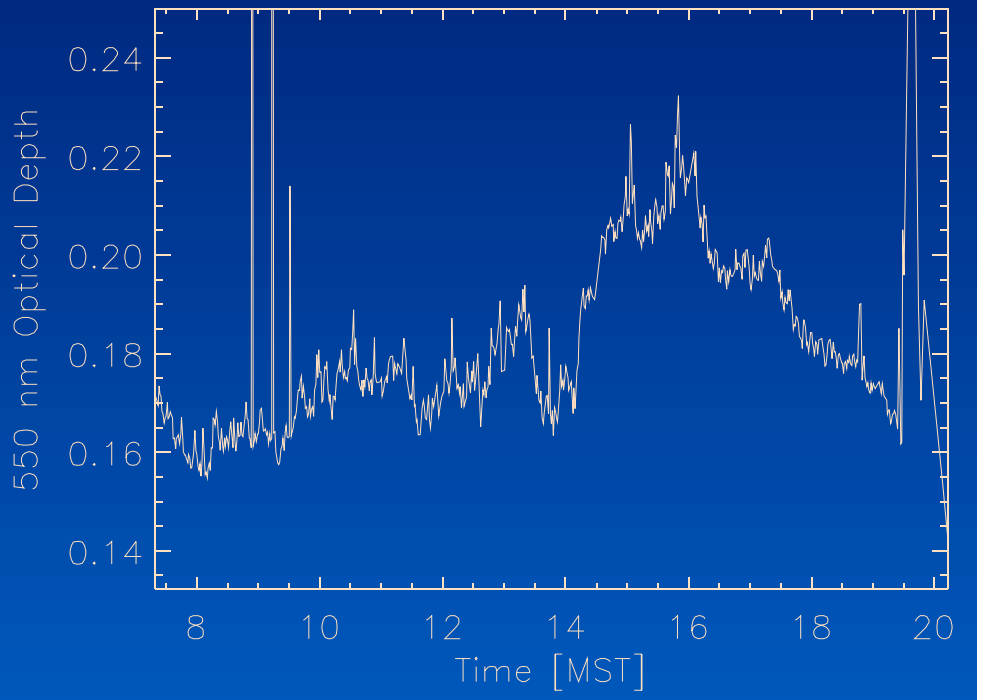
Example atmospheric results

Graphs below show the results from Ivanpah versus the most turbid day in Brookings

Ivanpah Playa

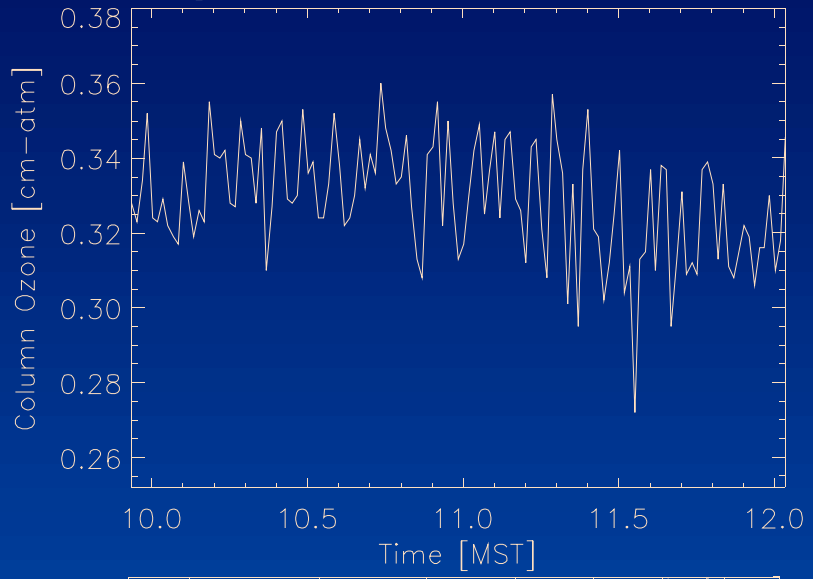


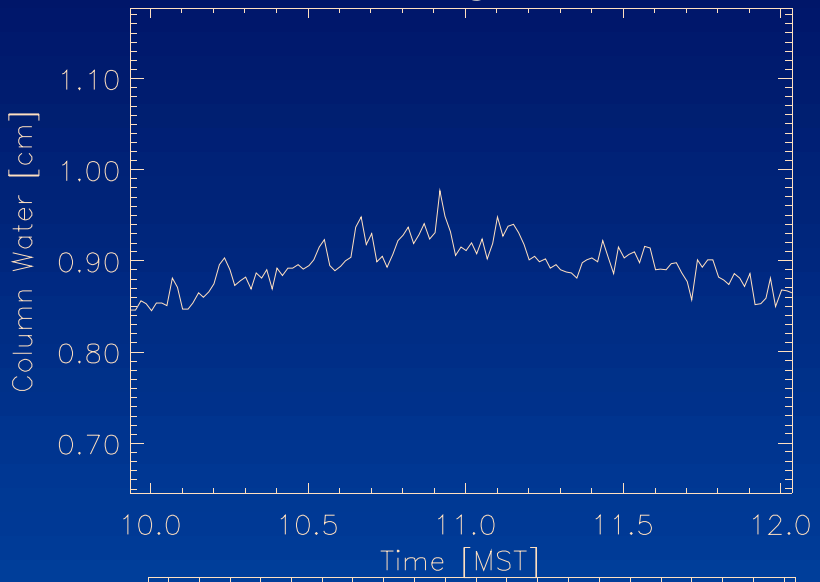
Brookings

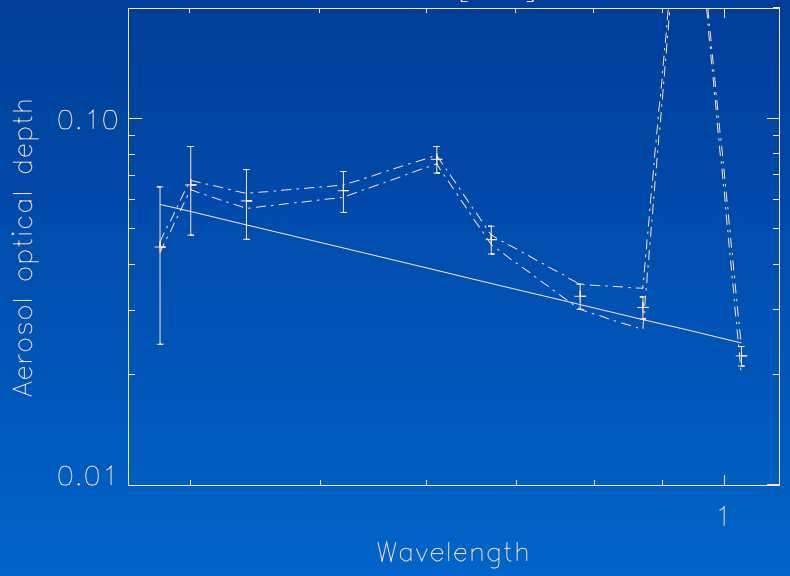


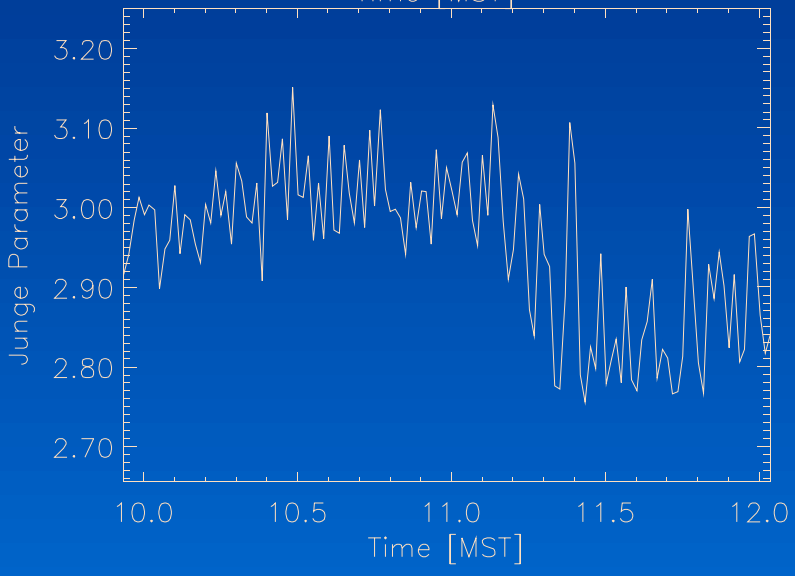
Example atmospheric results

Example results from Lunar Lake on July 16, 2001

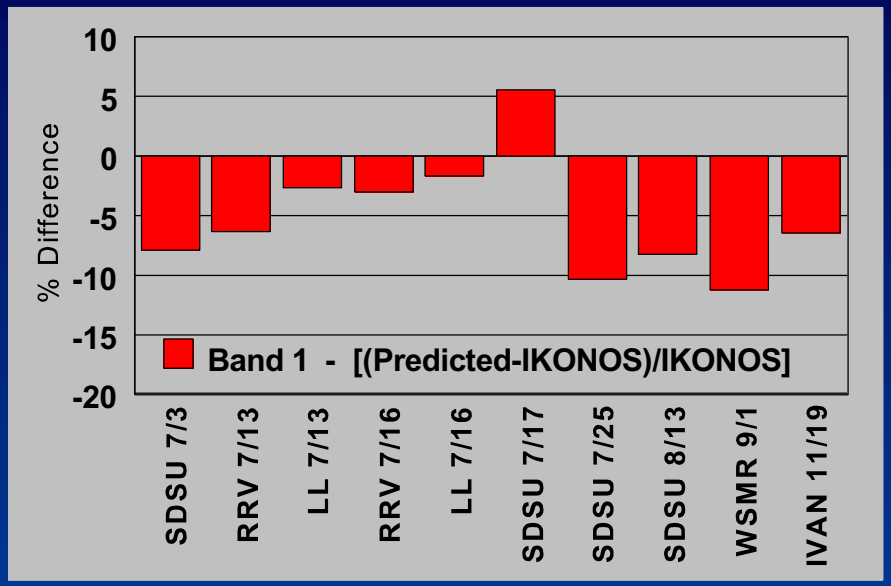


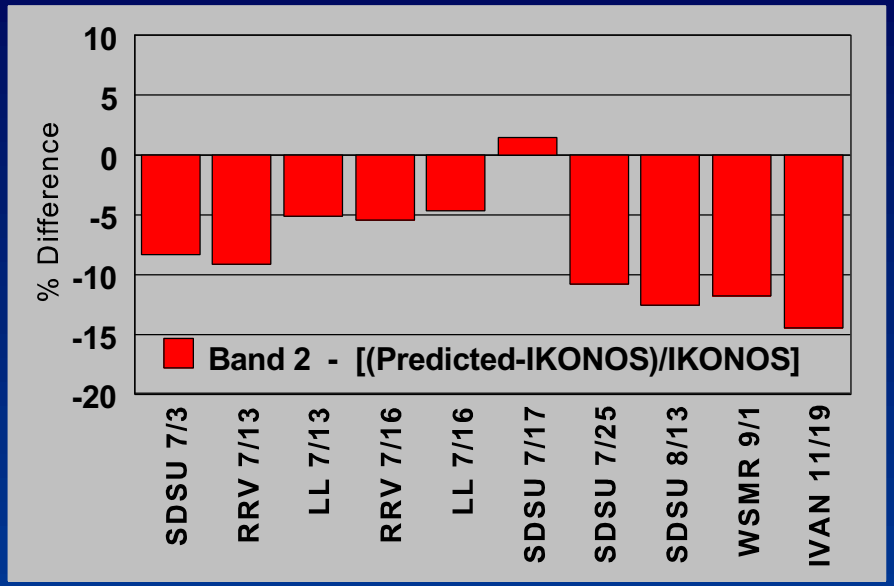


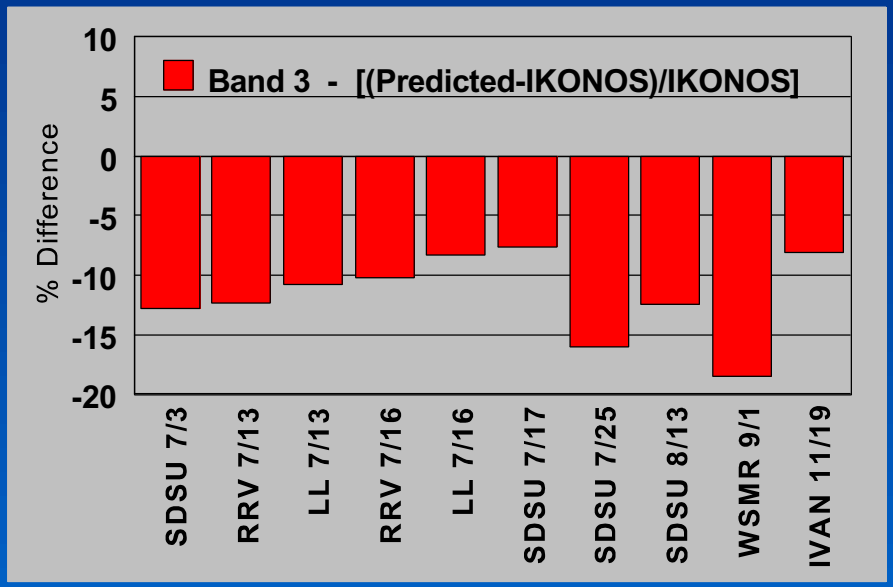


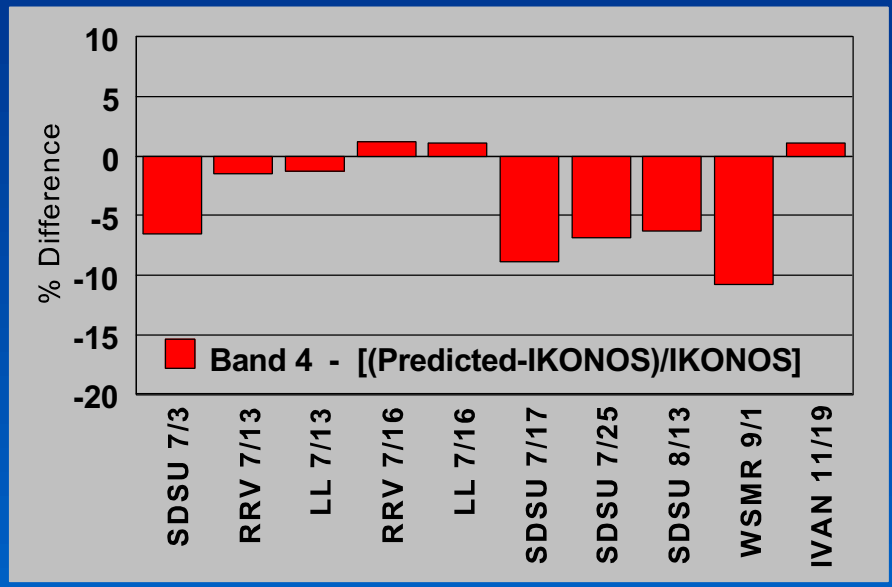


Summary of results

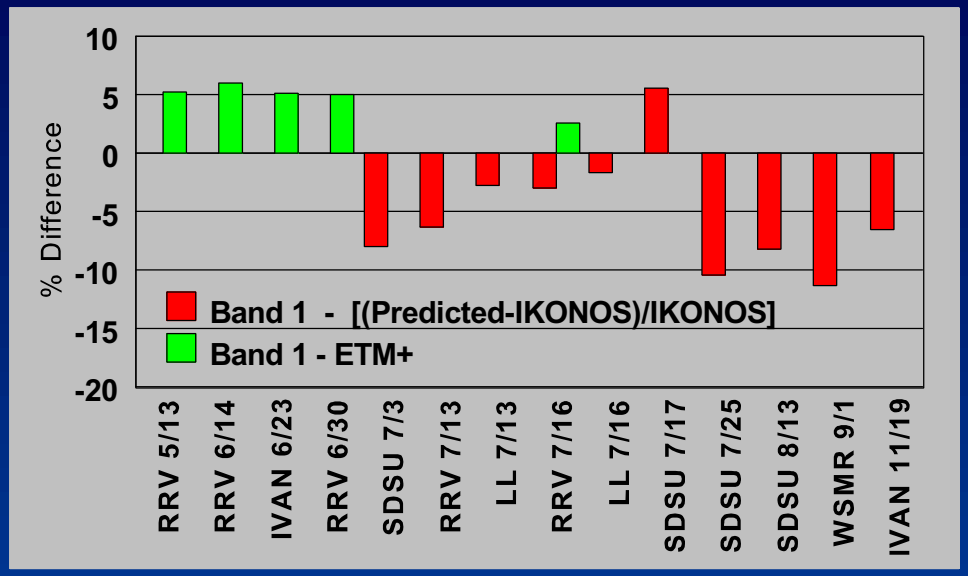


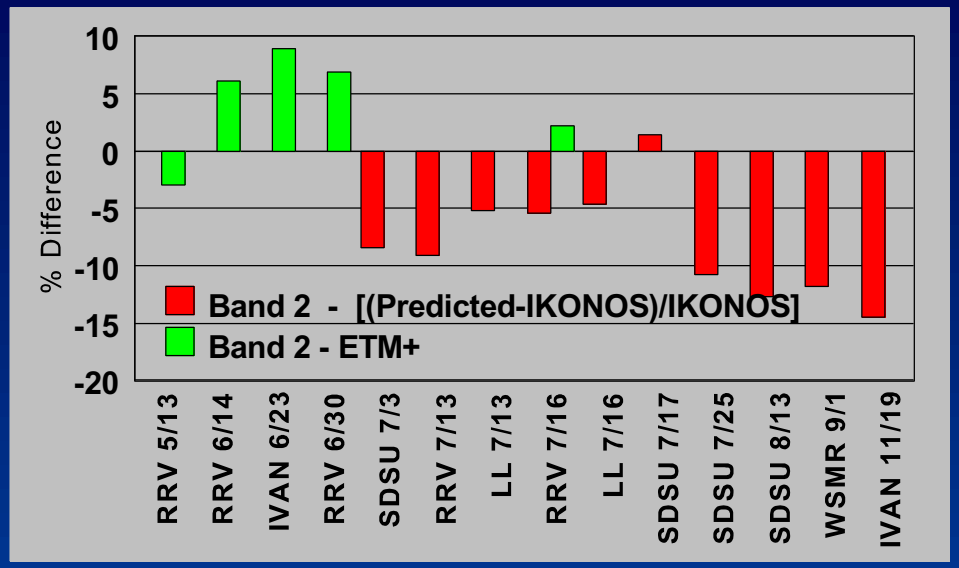


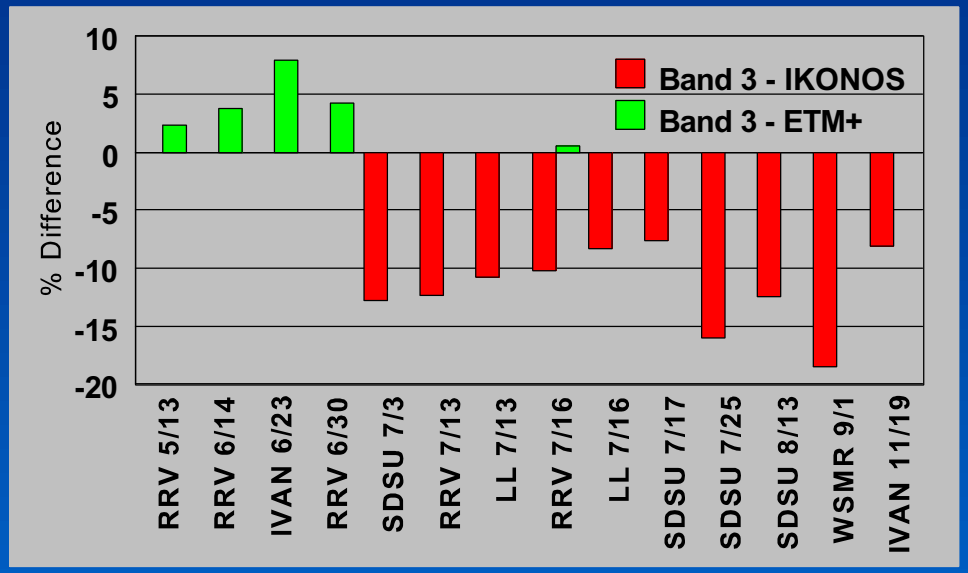


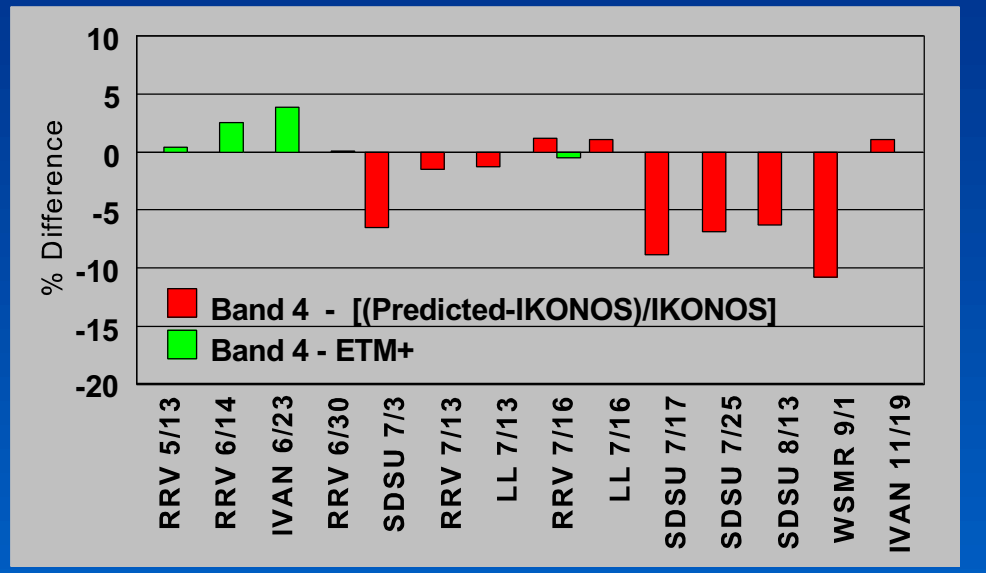


Comparison to ETM+ Results









Uncertainties - Atmosphere

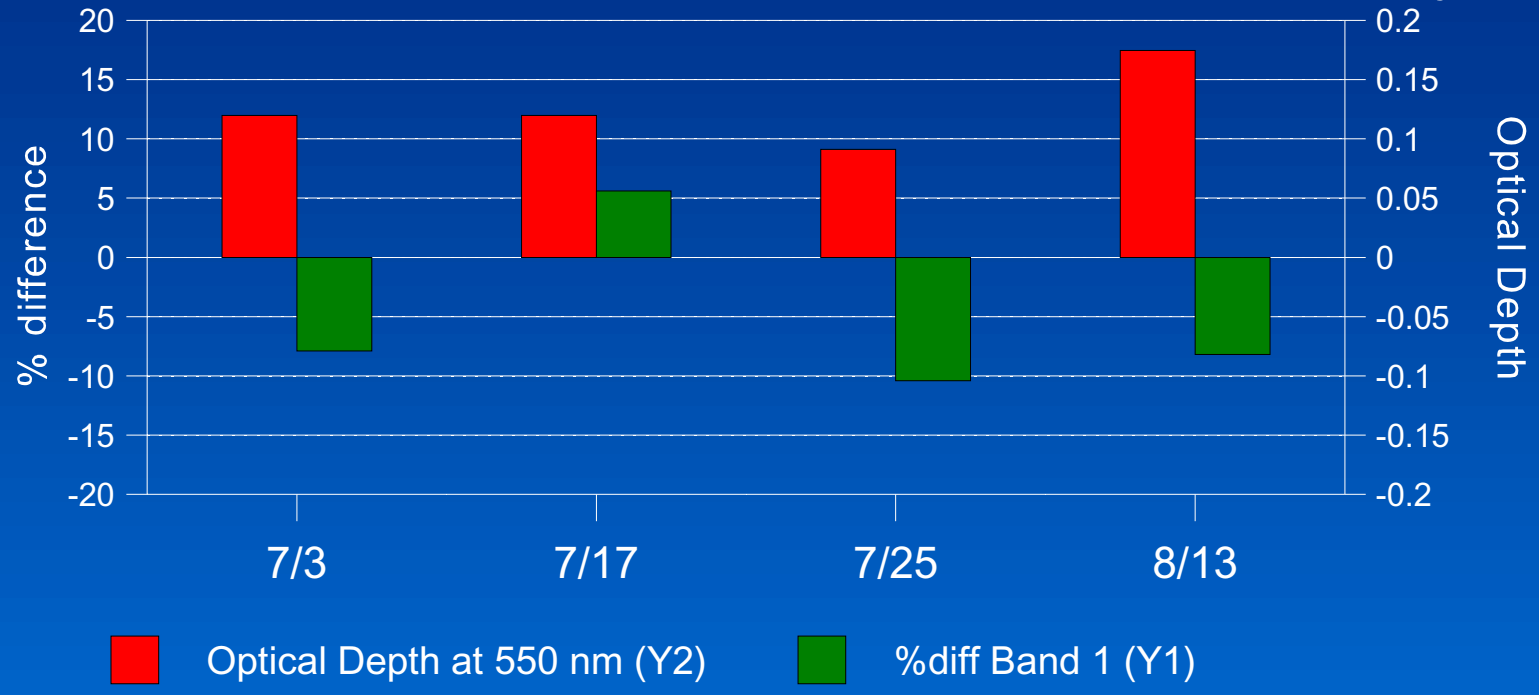
Errors in the atmospheric characterization are not a large source of uncertainty for the playa sites but can play a role for the Brookings site

- High reflectance of playa sites reduces effects of atmospheric uncertainties
- Changes in optical depth and index of refraction would lead to lower predicted radiances
  - IKONOS radiances exceed predicted in mostcases
  - Sensitivity study of input parameters indicated only a 1-2% effect from aerosol uncertainties
- Over dark sites such as Bands 1-3 at Brookings, atmospheric uncertainty can play a role
  - Calibration of solar radiometers leading to uncertainty in optical depths
  - Horizontal inhomogeneity leading to adjacency effects

Uncertainties - Atmosphere

Sensitivity study of input data from Brookings site indicates that atmospheric inputs could reasonably account for some of the differences

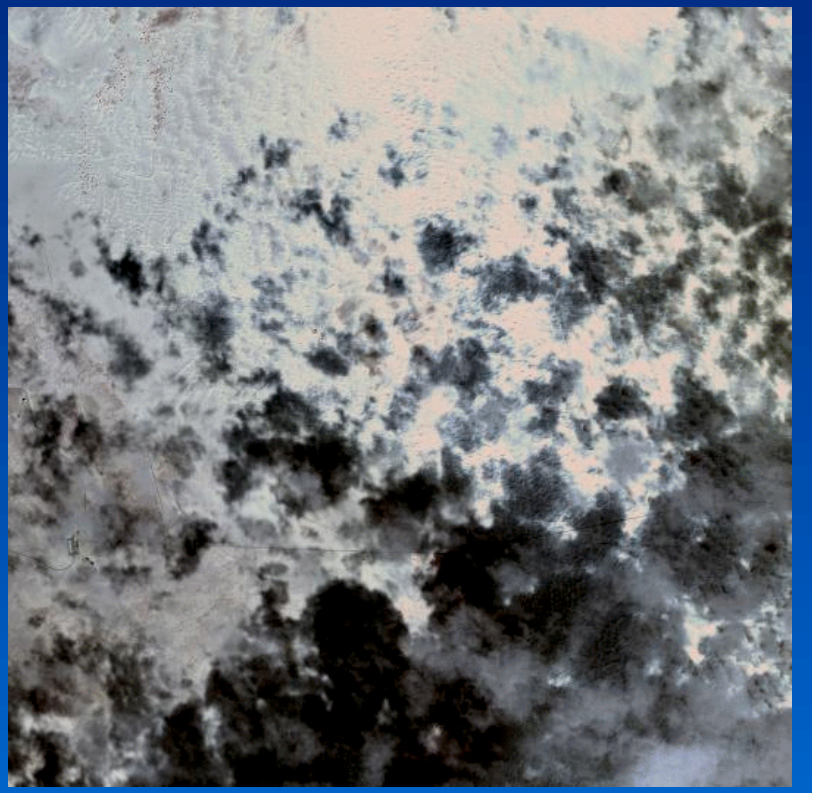
- However, figure below shows no trend with optical depth
- Similar results seen for other atmospheric parameters
- 0.02 error in optical thickness reduced differences by 2%



Uncertainties - White Sands data

From image below, it is clear that the White Sands data set is dominated by clouds

- Reflectance was measured on previous day under clear skies
- Results from sensors on Terra platform were consistent to within 3% of other calibrations at other sites on different dates
- Sensitivity study shows that atmospheric uncertainties cannot account for the difference
- Source of error must be somewhere else
  - Surface reflectance changes
  - Adjacency effects



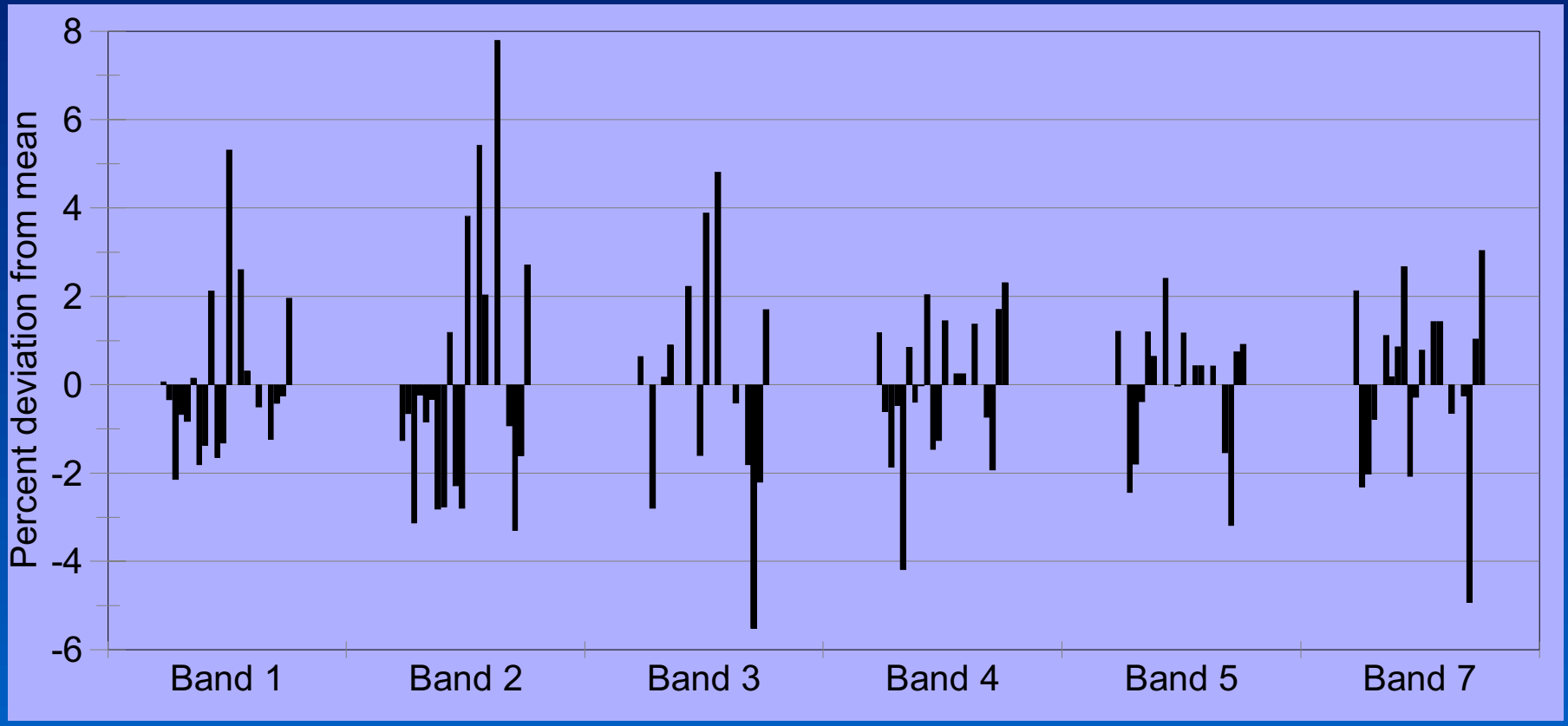
Uncertainties - surface reflectance

Uncertainties in surface reflectance are the dominant source of error in the method at the playa sites

- Intercomparisons between other groups show consistent results with UofA
  - Other groups have panels calibrated at the UofA
  - Groups use different sampling approaches
- Still find 2-3% differences between instruments
  - Two ASDs operated by the UofA
  - ASDs operated by SDSU and UofA
- Site Uniformity is the biggest difference between the Brookings and playa sites
  - Studies by SDSU show up to a 4% uncertainty due to this effect
  - UofA has noted similar issues with use of a small asphalt test site in Tucson

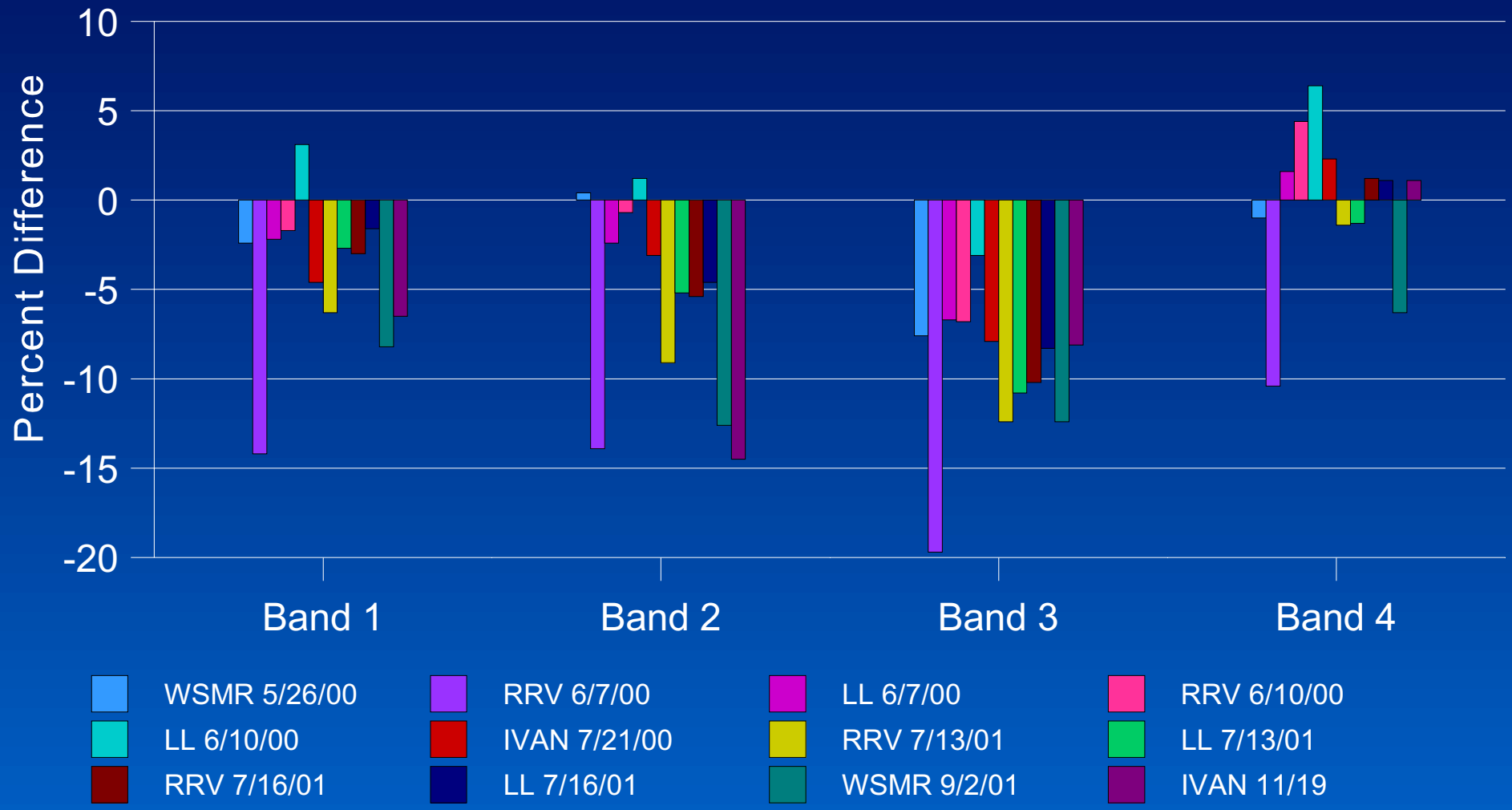
Uncertainties in terms of precision

Work with Landsat-7 ETM+ indicates that while the RSG does have outlier results, overall 1- σ precision of method is approaching 2%



2000 and 2001 Results

Using the appropriate radiometric coefficients for each data set, the graph below shows results from the 2000 and 2001 and field seasons



Conclusions and Final Remarks

- Agreement between ground-based measurements and IKONOS output is between 4% and 12%
  - IKONOS consistently reports higher radiances than vicarious results
  - Band 4 shows best agreement and band 3 worst
- Using only playa sites without White Sands gives similar % differences
  - Band 4 difference is 0.1%
  - Standard deviations of averages are less than 2% (except band 2)
  - Bands 2 and 3 shows a 8-10% differences which exceed the estimated uncertainties of the vicarious results
- Comparison with ETM+ results indicate that the agreement between IKONOS and EMT+ should be on the order of 10%

Final remarks

- Confident that the accuracy of the IKONOS radiometric calibration is better than 10% across a wide range of radiance levels
- Use of data from 2000 indicates better agreement
- Overall conclusion is that IKONOS is understood radiometrically and appears to be well-behaved

And a well-behaved sensor is a good thing, because you don't want to know where we send the poorly-behaved sensors